Phys.425 Statistical and Thermal Physics--Fall 2014

Class Hours:10:00-10:50AM MWF; Class Room: GRB W211

Instructor: Huey W. Huang

Office Hours: MTuTh 2-5 or by appointment at Rm 252 Brockman Hall

Email: hwhuang@rice.edu with subject: Phys425

Textbook: Fundamentals of Statistical and Thermal Physics by F. Reif
ISBN(13):978-1-57766-612-7 (Waveland Press, Inc)
[Earlier versions by McGraw-Hill (ISBN:0-07-051800-9) should be the same.]

This is a course on Thermodynamics and an introduction to Statistical Mechanics. The prerequisites are introductory physics, elementary partial differential calculus, and rudimentary concepts of quantum mechanics. Thermodynamics is mathematically simple but conceptually difficult. You are expected to spend time thinking about it. The text book by Reif is excellent. There are lots of stuff in it (the textbook has been used for an undergraduate introductory course as well as a graduate course at Berkeley). I don't expect you to read all of it, but it is important to know what are in there, so you can look it up when needed. For the course you only need to read enough to understand the lectures and do the homework. The subjects to be covered are listed in the content sheet next page.

One reason for choosing this textbook is that it contains a large number of problems. There is no better way of testing your comprehension by trying out these problems. I will assign homework in Owl-space at least a week ahead of the due day. One set of homework will be due every Wednesday (unless specified otherwise). You are asked to turn in your homework at the beginning of the class on the due day. We will then discuss the homework solutions in class. Homework discussion is part of the lectures—no printed solutions will be distributed, because I found students don't think as hard if the solutions are readily available. Unless you have a legitimate excuse, late homework is not acceptable.

It is impossible to overemphasize the importance of homework. You learn the most from doing the problems yourself, including making and correcting mistakes. You are allowed to discuss homework with fellow students and with me, but ONLY after you have tried the problems yourself. Note: the first step of the solution is usually the key; the rest is usually straightforward. If you habitually rely on others to help you with the first step, you probably have not learned the subject.

The course grade will be determined by the homework (50%), a mid-term exam (20%), and a final (30%). Both mid-term and final will be take-home, pledged exams.

* Any student with a documented disability needing academic adjustments or accommodations is requested to speak with me during the first two weeks of class. All discussions will remain confidential. Students with disabilities should also contact Disability Support Services in the Ley Student Center.

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CONTENT (important: use the notations of the textbook)

Chapter 1: Random walk.
Binomial/Gaussian/Poisson distributions; $1/\sqrt{N}$ rule.

Chapter 2/Chapter 3: Introduction to the definition of thermodynamic states.
System/environment, macroscopic variables, **the maximum principle of entropy**, statistical interpretation, temperature, concavity of entropy, quasi-static/reversible/irreversible processes.

Chapter 4:
4.1 **The maximum principle of entropy implies the minimum principle of energy**.
4.2. Work, heat, $dE = \Delta Q + \Delta W = TdS - PdV$, the first law, the second law, the third law.
4.3. $dE = TdS - PdV + \sum \mu_i dN_i$, equilibrium conditions, stability conditions.
4.4. Ideal gas. T_{tp}=273.16, $k_B = 1.38 \times 10^{-16}$ergs/deg, $R = 8.31$ joules/mol·deg
4.5. Extensive/intensive parameters, absolute entropy, stability conditions, susceptibilities, heat capacity/specific heat, compressibility.

Chapter 5:
5.1 The minimum principle of energy, convexity of energy
5.2 Legendre transforms and the minimum principles of free energies
5.3 Changes of independent variables, partial differentiations, Maxwell relations
5.4 Ideal gases, proof of $E = E(T)$, Joule's experiment of free expansion, C_V, C_P, isothermal/adiabatic expansion.
5.5 $C_P = C_V + VT\frac{\alpha^2}{\kappa}$; throttling process.
5.6 Heat engine, Carnot cycle.

Chapter 6/Chapter 7:
1. **The principle of statistical mechanics**; microcanonical ensemble, canonical ensemble, grand canonical ensemble. Example of spins in H.
2. Partition function, relation to thermodynamics.
3. Ideal monatomic gas, Gibbs paradox, equipartition principle, simple applications.

Chapter 7: **Kinetic theory of gases**
Maxwell velocity distribution, mean values, number of molecules striking a surface.

Chapter 8: Equilibrium between phases, Gibbs' phase rule, Clausius-Clapeyron relation, van der Waals equation, Maxwell construction, phase transitions, chemical equilibrium, law of mass action. Le Chatelier's principle.

Chapter 9: Quantum statistics of idea gases

Grand canonical ensemble, Fermi-Dirac distribution, Bose-Einstein distribution, Boltzmann distribution, black-body radiation, Bose-Einstein condensation.